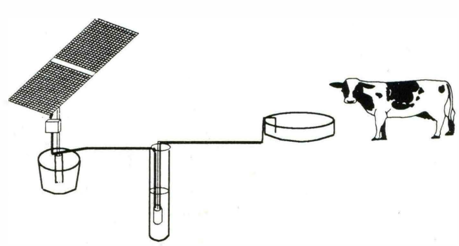
WATERING LIVESTOCK

With

SOLAR WATER PUMPING SYSTEMS



FOREWORD

This handbook was written to provide livestock producers with the basic information needed to better understand solar powered water pumping systems. It is not meant to be a detailed instruction manual on the installation of these systems. The information contained in this handbook comes from several years of hands-on experience with solar water pumping systems and from credible sources of information on the subject of watering livestock.

The Missouri Department of Conservation has sponsored this effort because we recognize the importance of both Missouri's aquatic resources and it's livestock industry. We believe the two can lead a healthy coexistence if the stream channel and it's bordering vegetation are spared from too much livestock use and if livestock can obtain the quality and quantity of water needed for efficient production. In order to meet these needs satisfactory fencing and water pumping systems need to be installed. This handbook is meant to introduce solar powered water pumping systems but acknowledges that several other types are also practical for Missouri's livestock producers.

For information about cost-sharing programs contact your local office of the Missouri Department of Conservation , Natural Resources Conservation Service, or the Soil and Water Conservation District.

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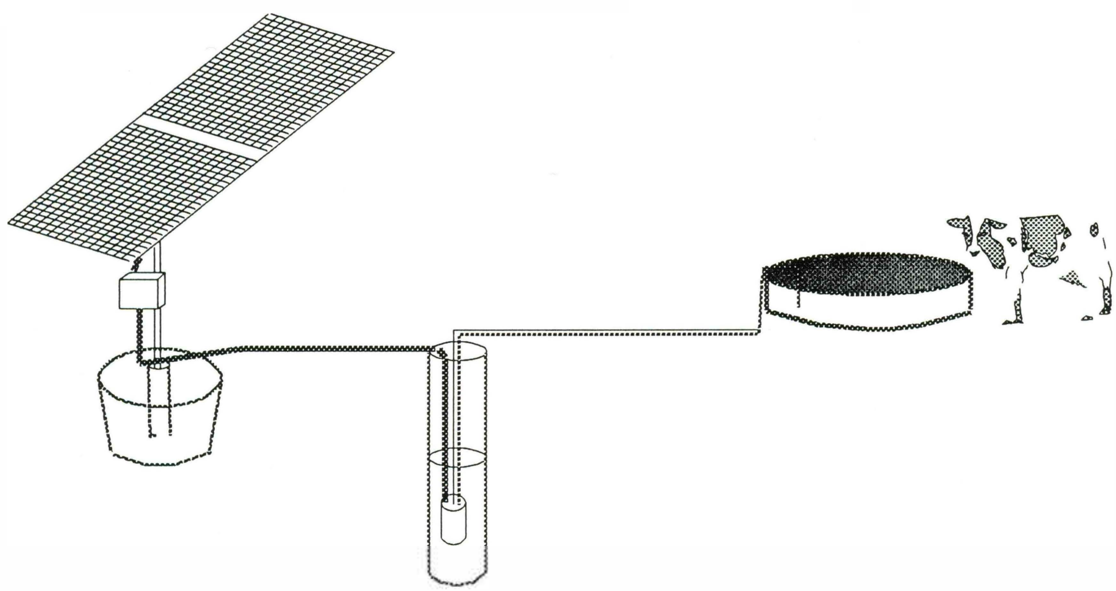

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INTRODUCTION

For a number of years Missouri livestock producers have been urged to fence their livestock from streams and ponds. These requests bring to mind the question:

WHY PUMP WATER TO LIVESTOCK WHEN YOU CAN LET THEM INTO A POND OR STREAM?

A successful livestock operation needs an ample supply of good quality water to maintain animal health and profitable production. Livestock producers who keep their animals out of streams and ponds will gain the following benefits:

- **Improved Water Quality and Livestock Production Means Higher Profits-** Streams and ponds fenced from livestock do not receive livestock manure and silt from erosion, so water quality is protected. Good, cool water can increase beef production by 0.3-0.4 pounds per day and dairy production by 5 pounds of milk per day per cow. Water contaminated with manure may develop toxic blue-green algae which can poison livestock, causing muscle tremors, liver damage, and death. Other examples of problems from poor water quality are high nitrates that interfere with the animals ability to absorb oxygen, high salinity that produces a form of dehydration, and bacteria that cause diseases, such as leptospirosis and brucellosis.

- **Reduction in Soil Erosion Means Lower Operating Costs -** Fencing livestock from streams prevents streambank and gully erosion. Streambanks are not trampled and the streambank vegetation, that is so important to reducing erosion, is not grazed down and trampled. Money does not have to be spent on erosion control and property is not lost to excessive erosion.

- **Safer Watering Sites Means Fewer Veterinary Bills -** Hazards, such as cattle breaking through the ice or falling down stream banks and cattle mired in mud or swept away in floods, are avoided. In addition, the incidence of foot rot and foot injuries are reduced.

- **Improved Pasture Usage Means Higher Profits -** Watering locations can be placed to reduce the distance that cattle must walk to get to water. This improves use of the entire pasture, increases the amount of time cattle spend grazing, and spreads the manure so it fertilizes the pasture, instead of being left in the water supply to reduce water quality.

- **Better Fish and Wildlife Means Better Hunting and Fishing -** Fencing livestock from streams and ponds results in a healthy stand of trees along the edge of the water. This corridor of trees near the water produces much better habitat for both fish and wildlife.

Of course, if livestock are fenced from streams and ponds then water must be provided to them. A variety of pumping systems are available and each of these has its place as an alternative to watering livestock in a stream or pond. This handbook will highlight solar water pumping systems but several of the other sources of power available for water pumping, with their advantages and disadvantages, are listed in Table 1.

Solar water pumping systems were chosen to be highlighted because they are capable of meeting the water needs of most Missouri livestock producers who do not have electricity readily available at their watering location. Solar energy is a practical method for livestock watering because the sunniest time of the year is the time of highest water need. In addition, Missouri livestock producers need flexibility in their operations and solar water pumping systems can be portable and altered to fit your needs.

Table 1. Water pumping power sources and their inherent advantages and disadvantages.

POWER SOURCES	ADVANTAGES	DISADVANTAGES
Engine Generator	Locally available, reasonably priced, and are generally portable.	Requires fuel hauling, high maintenance, and are prone to flood damage.
Windmill	No fuel costs	Requires regular winds and significant maintenance. High initial cost and are not portable.
Utility Electricity	Provides standard 120 volt power at low cost if utility line is nearby.	High installation and maintenance costs if transmission line must be installed. Not portable.
Solar	Requires no fuel and are low maintenance, portable, and can be designed not to flood. Reasonable initial cost.	It is still unfamiliar technology to many people. Low volume pumps require more time to pump the needed water.
Water Ram	Requires no fuel, are low maintenance, portable, and low in initial cost.	Requires a constant flow of water and several feet of head for operation.

ANSWERS TO COMMON QUESTIONS ABOUT SOLAR POWERED WATER PUMPING

How do solar panels work?

Solar electricity, or photovoltaic power, is produced when the sun shines on a solar cell that is made of silicon. The sunlight causes electrons to move from one side of the cell to the other. This flow of electrons is electricity, which is directed into an attached electrical circuit. Many of these small solar cells are attached together to form a solar panel. Solar panels are then connected together to supply the amount of electricity needed for any given situation, such as solar powered electric fencers. Most solar water pumping systems operate on 12 or 24 volts and 3 to 4 amps of direct current.

How reliable are solar panels?

Solar panels are very reliable and maintenance free; ten to twenty year warranties are common. In a survey of 150 ranchers in the western United States who use solar water pumping, 100% rated the performance of the solar panels as good to excellent.

When is it practical to use solar panels instead of utility power?

If you have utility power available to serve your needs then a solar system is not practical. But installing and maintaining a transmission line from the utility line to a remote location can be very expensive. A number of Rural Electric Cooperatives advocate the use of solar pumps due to the expense of installing a line that will only be used for pumping water. This expense varies with the type of terrain that must be crossed but, generally speaking, it is more cost effective to use solar water pumping if the distance of the line is greater than one-third of a mile.

What do you do when it is cloudy?

Even when it is cloudy solar panels produce some electricity, but to ensure that ample water is always available for livestock the solar water pumping system is designed with about three days of storage capacity. This is three days of water storage in systems where the pump is driven directly by the solar panels or three days of electrical storage in batteries for those systems where the pump is run by batteries.

Should I use a battery operated system or one that is directly driven by the solar panels?

Whenever possible direct drive systems should be selected because they are less expensive and require less maintenance. However, battery operated systems can offer more flexibility in meeting water needs and are a reliable option.

What can I do if my system needs to be expanded?

A solar system can be designed for easy expansion to increase the volume of water pumped; it is often simply a matter of adding more solar panels. Planning for a possible increased need should be taken into account during the initial design and setup of the system.

What are the capabilities of solar water pumping systems?

Solar water pumping systems can be designed to meet the needs of any livestock producer. Solar pumping systems that can pump thousands of gallons of water a day and can pump water vertically hundreds of feet are available. The capability of solar water pumping is not a concern but selecting the right pumping system to meet your needs is important.

What water sources can I pump water from?

Streams, ponds, springs, deep wells, and shallow wells are all possibilities. Obviously the water should be clean and free of sand or other particulate matter. Shallow wells in the floodplain can be an economical and practical water source but ask your well driller to obtain clearance for this type of well from: Section Chief, Wellhead Protection Section, P.O. Box 250, 111 Fairgrounds Road, Rolla, Missouri, 65402-0250, (573) 368-2165. Also, check with your local authorities for code and permit requirements.

How difficult are solar water pumping systems to install?

Solar systems are no more difficult to install than any other type of watering system. The solar panels are mounted on a metal frame that is usually supplied by the manufacturer. The electrical wiring is relatively simple and can be done by anyone with basic knowledge of electrical circuits. Most of the work involved is installing water lines, watering tanks, and fencing, which is done in the same manner as with any other type of water pumping system.

What will a solar water system cost?

The cost of a system is highly variable because the equipment needed is dependent upon the water needs and physical layout of each individual livestock producer. In addition, several government agencies have programs that offer 75% cost sharing on these systems. The total cost of a system can vary from several hundred dollars to several thousand dollars. Your cost will be significantly reduced when you participate in a cost-share program. Refer to the case histories described in this handbook to get a better understanding of cost.

Is financial assistance available for the purchase and installation of solar watering systems?

At the time this handbook was printed the Missouri Department of Conservation, Department of Natural Resources Soil and Water Conservation Districts, and the U.S. Department of Agriculture all have cost-sharing programs available. Some programs cover as much as 75% of system costs. Consult with your local offices of these agencies to determine what assistance is available.

Where would I purchase a solar water pumping system?

Several reputable manufacturers offer complete systems and provide technical assistance in designing, installation, and maintenance of their systems (Refer to Appendix 1).

SOLAR WATER PUMPING SYSTEMS

Types of Systems

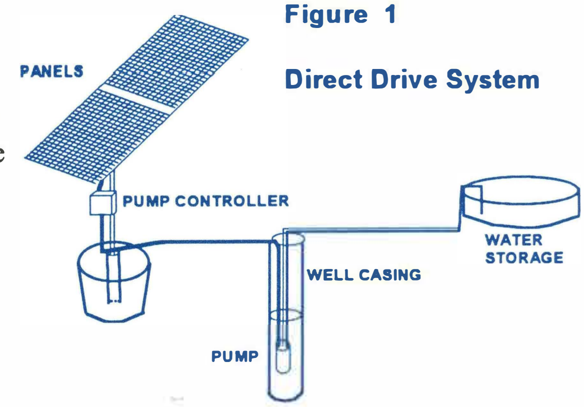


Figure 1

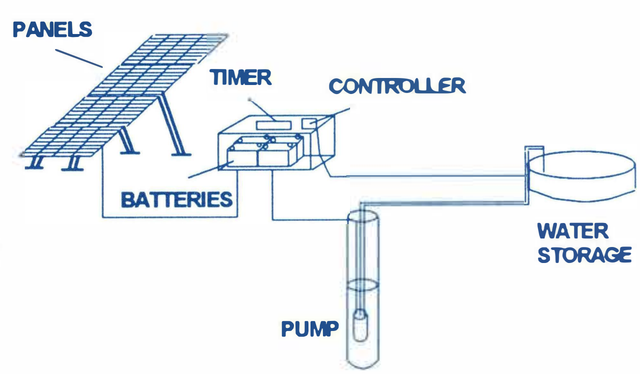
Direct Drive System

There are basically two types of solar water pumping systems, those that do not use batteries (direct drive systems) and those that do. Direct drive systems (Figure 1) consist of solar panels, an electronic controller, and the pump itself. The controller is very important because it matches the output of the solar panels with the demand of the pump. For example, during low light levels, such as early morning hours, the controller will alter the voltage and amperage from the panels to increase the current input to the pump motor so that it will start pumping. Without this controller the pump would not start pumping until later in the morning when the light level was much higher.

Direct drive systems are simple in design but only pump water during daylight hours and pump at a reduced level during cloudy periods. Since livestock need water every day these pumping systems are sized to store extra water on sunny days so that it is available on cloudy days and at night. It is very important that this extra water storage be designed into the system. At least three days of water need must be stored to ensure that livestock have ample water regardless of sun conditions.

Battery operated systems (Figure 2) are used when it is necessary to pump water regardless of whether or not solar energy is available or when water storage is impractical. Battery operated systems store 3 days of electricity needs to get through cloudy periods. These systems are more complicated because the batteries power the pump while the solar panels are used to recharge the batteries, requiring more components than direct drive systems. However, battery operated systems do offer more flexibility. For example, spring or well water can be pumped throughout the night and day to keep the system from freezing in cold weather months. Or if the water need is higher in the early morning hours, the water can be pumped at night so it is available when it is needed most. A timer is needed to turn the pump on and off at the chosen times.

Figure 2 - Battery Equipped System



Deep cycle batteries, that are designed to be discharged 50-80%, are best suited for solar water pumping. When batteries are used they need to be maintained and there will be replacement costs several times during the life of the pumping system. Follow the advice of the solar equipment supplier when purchasing batteries.

Solar Water Pumps

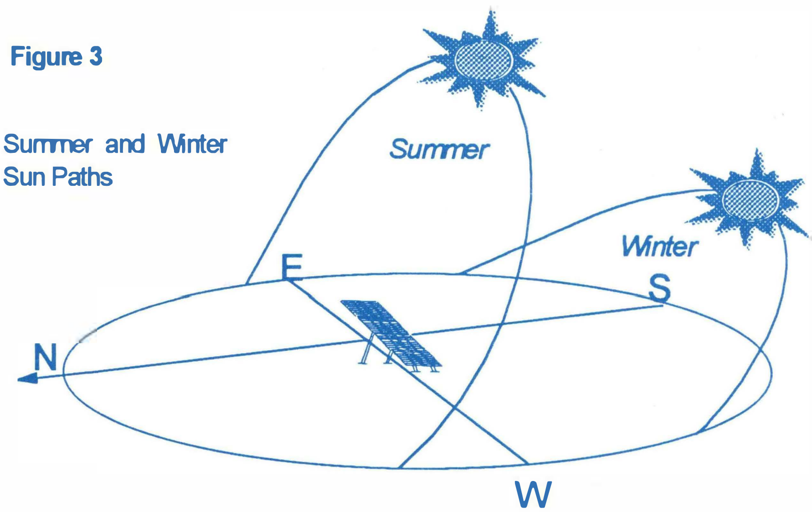
Solar water pumps are available in above ground and submersible models. Most of these are either centrifugal or diaphragm type pumps but other types are also used. Although a wide range of sizes are available most pumps used in livestock watering applications are low volume, yielding 2 - 4 gallons per minute. Low volume pumping keeps the cost of the system down by using a minimum number of solar panels and using the entire daylight period to pump water. This extended water pumping time requires some patience by the owner that is used to pumping large volumes of water in a short amount of time.

Sun Trackers

Sun trackers are a type of solar panel mount that move the panels throughout the day to keep them facing directly toward the sun. This increases the efficiency of the panels by collecting the maximum amount of sun and decreasing the amount that is reflected and not used. Trackers increase the amount of water that your system is able to pump and are most efficient during the summer months when the sun is high in the sky and least efficient in the winter months, Figure 3. During the summer, trackers can increase the output by 25 to 40%.

Figure 3

Summer and Winter Sun Paths



It might seem that increasing the efficiency of the pumping system would always justify the use of a sun tracker. However, the decision to use a tracker is based not only on its ability to increase efficiency but also on the cost effectiveness of adding the tracker as opposed to adding an additional solar panel to achieve the same water pumping capacity. The tracker is also another moving part that will require maintenance. Ask your solar equipment supplier which option will serve your needs best.

Controllers and Timers

Electronic controllers match the output of the solar panels with the needs of the pump. These controllers work with variable weather conditions to increase the efficiency of the pumping system by 10-15%. One of the most important benefits of a controller is that it allows the pump motor to be started at low sun levels. Some of the important features to look for in a controller are:

- Built-in protection for: over heating, reverse polarity, voltage surges, inadequate output current, and lightning strikes.
- The option to hook up a remote float switch.
- The option to hook up a cut-off circuit in case of low water in the well.
- An on\off switch and a power indicator light.
- The controller should be weatherproof and have well designed electrical wire connectors.

Controllers are an important part of a solar water pumping system because they add efficiency and flexibility to the system. In addition, the controller is one of the least expensive components of a solar water pumping system.

A timer can be added to a battery equipped system to turn the pump on and off at preselected times. Timers are available with keypads that allow you to set the desired pumping times for months in advance.

Plumbing and Electrical Wiring

The plumbing fixtures and pipe used in solar water pumping systems are the same standard items used in everyday plumbing. One-inch or 3/4 inch PVC pipe are commonly used. It is especially important to have a leak proof system because a leak in these low volume pumping systems can have a significant effect on the amount of water you receive from the system. Also it is recommended that as few corners as possible be used in the plumbing so that pipe friction is kept to a minimum.

The electrical wiring used is also of standard types and sizes, but wiring that will be exposed to the sun should have a sunlight resistance rating. The connecting of the electrical components is generally quite simple and can be completed by anyone who has a basic understanding of electrical circuits. It is important to be aware of the distance between electrical components because voltage loss over the wire can be a problem in low voltage circuits. Table 2 provides the maximum recommended distance for various sizes of wire that are carrying various amperages. These distances allow for a 3% drop in voltage.

Table 2 - Maximum one-way wire distance (feet) for 24 volt circuits.

	AWG WIRE SIZE				
	14	**12**	**10**	**8**	**6**
1 Amp	110	175	279	445	705
2 Amps	55	87	139	222	352
4 Amps	27	43	69	111	176
6 Amps	18	29	46	74	117

SELECTING A SOLAR WATERING SYSTEM

A watering system has three basic components; the water source, the watering location, and the plumbing required to connect the two. The first step to developing a watering system is to determine the amount of water needed for each month of the year.

Determining Your Water Needs

Determining your monthly water needs is vital for selecting a system that is properly sized because the available solar energy varies with each month of the year, and livestock water needs vary from one season to the next. Livestock water needs vary due to a number of factors such as pregnancy, lactation, physical activity, type of feed, and average air temperature. Table 3 provides the approximate number of gallons of water needed per day by various types of beef cattle for each month of the year.

Table 3 - Estimated Daily Water Intake of Beef Cattle

Month	Mean Temp.	Cows		Bulls	Growing Cattle[2]			Finishing Cattle			
		Nursing Calves[1]	Bred Dry Cows & Heifers		400 Lbs	600 Lbs	800 Lbs	600 Lbs	800 Lbs	1000 Lbs	1200 Lbs
	°F	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)	(Gal.)
Jan.	36	11.0	6.0	7.0	3.5	5.0	6.0	5.5	7.0	8.5	9.5
Feb.	40	11.5	6.0	8.0	4.0	5.5	6.5	6.0	7.5	9.0	10.0
Mar.	50	12.5	6.5	8.6	4.5	6.0	7.0	6.5	8.0	9.5	10.5
April	64	15.5	8.0	10.5	5.5	7.0	8.5	8.0	9.5	11.0	12.5
May	73	17.0	9.0	12.0	6.0	8.0	9.5	9.0	11.0	13.0	14.5
June	78	17.5	10.0	13.0	6.5	8.5	10.0	9.5	12.0	14.0	16.0
July	90	16.5	14.5	19.0	9.5	13.0	15.0	14.5	17.5	20.5	23.0
Aug.	88	16.5	14.0	18.0	9.0	12.0	14.0	14.0	17.0	20.0	22.5
Sept.	78	17.5	10.0	13.0	6.5	8.5	10.0	9.5	12.0	14.0	16.0
Oct.	68	16.5	8.5	11.5	5.5	7.5	9.0	8.5	10.0	12.0	14.0
Nov.	52	13.0	6.5	9.0	4.5	6.0	7.0	6.5	8.0	10.0	10.5
Dec.	38	11.0	6.0	7.5	4.0	5.0	6.0	6.0	7.0	8.5	9.5

[1]Cows nursing calves during first 3 to 4 months after parturition – peak milk production period.
[2]Requirement will be a little less for wintering on range.

Table prepared by Paul Q. Guyer, University of Nebraska and adapted from Texas Agricultural Extension Service bulletin BCM-16.

Following is an example of how to determine the average daily water needs for each month of the year on a typical cow\calf operation:

Example #1 - Bob and Betty have a cow/calf operation in which they need to water about 45 cows and 2 bulls year around. The 45 cows have nursing calves from February through June and the calves are sold for finishing in October. They also need to water an average of 20 head of heifers each month of the year. Table 4 shows how to determine their water pumping needs.

Table 4 - Bob and Betty's water needs. Values are rounded up to the nearest gallon.

Month	Cow/Calf Pairs	Growing Cattle (400 lb.)	Heifers and Bred Dry Cows	Bulls	Daily Water Needs
January	none		65 x 6 gal.= 390	2 x 7 gal.= 14	404 gal.
February	45 x 11.5 gal.= 518		20 x 6 gal.= 120	2 x 8 gal.= 16	654 gal.
March	45 x 12.5 gal.= 563		20 x 6.5 gal.= 130	2 x 8.6 gal.= 18	711 gal.
April	45 x 15.5 gal.= 698		20 x 8 gal.= 160	2 x 10.5 gal.= 21	879 gal.
May	45 x 17.5 gal.= 788		20 x 9 gal.= 180	2 x 12 gal.= 24	969 gal.
June	45 x 17.5 gal.= 788		20 x 10 gal.= 200	2 x 13 gal.= 26	1014 gal.
July		45 x 9.5 gal.= 428	65 x 14.5 gal.= 943	2 x 19 gal.= 38	1409 gal.
August		45 x 9 gal.= 405	65 x 14 gal.= 910	2 x 18 gal.= 36	1351 gal.
September		45 x 6.5 gal.= 293	65 x 10 gal.= 650	2 x 13 gal.= 26	969 gal.
October		45 x 5.5 gal.= 248	65 x 8.5 gal.= 553	2 x 11.5 gal.= 23	824 gal.
November			65 x 6.5 gal.= 423	2 x 9 gal.= 18	441 gal.
December			65 x 6 gal.= 390	2 x 7.5 gal.= 15	405 gal.

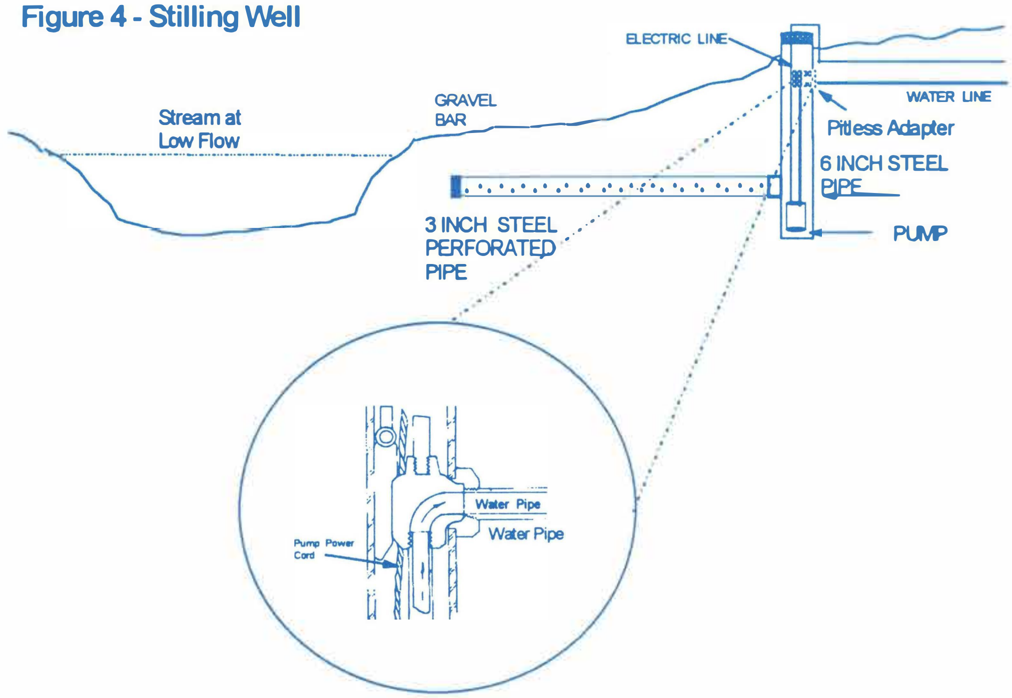
The daily water needs determined from Table 3 will give you a good estimate but it is wise to plan for an increase in the amount of water needed. Add any additional water needs that you foresee to the numbers you derived from Table 3. Even if you do not expect any additional needs, add 10 - 20% to ensure against the unexpected. After determining your total water needs you will need to know if you have a water source that can meet those needs.

Water Sources

Water can be pumped from any source that provides good quality water with low levels of sand or other particles that could clog or damage the pump. If there is any question about the quality of the water it should be tested before plans are made to use it for livestock watering. Ponds, streams, deep wells, springs, and shallow floodplain wells are all possible water sources but each requires special consideration.

Streams - It is important to plan for high flows, including flood events, when deciding the type of pump to use, how to install it, and how to install the solar panels. The solar panels can be mounted on poles to keep them above flood levels, and it is generally best to use a submersible type of pump so that it can be protected inside a well casing. A stilling well apparatus, similar to Figure 4, is a good way to obtain water from the stream and keep the pump out of harms way.

Figure 4 - Stilling Well



With this apparatus the water is filtered through the gravel so it provides cleaner water than would be delivered from an intake pipe located in the stream. This installation technique may not be practical in those areas of Missouri where the streams do not contain gravel bars. Using a stilling well eliminates maintenance associated with an intake filter and repairs required of the intake pipe. The waterline can be installed below the frost line by using an underground connector called a pitless adapter.

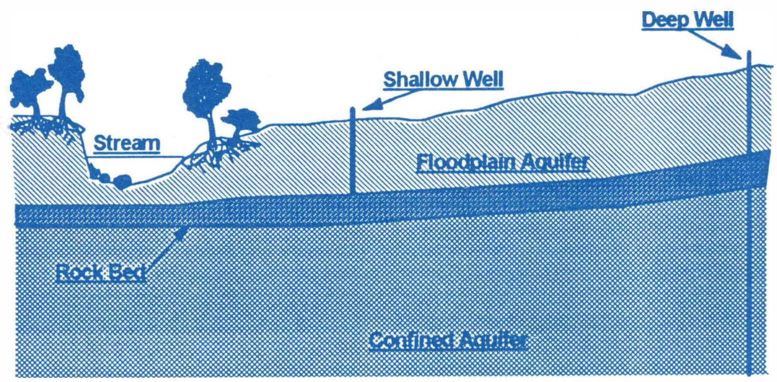
- Ponds - Upland ponds are good water sources to pump from because less expensive, above ground pumps can be used. However, it is common for these ponds to be located a considerable distance from bottom land pastures so running waterlines may not be cost effective.

- Deep Wells - It is a common misconception that solar pumps are not capable of pumping water up from deep wells. But in fact, diaphragm solar pumps are designed to pump from depths greater than 220 feet, centrifugal pumps from as deep as 600 feet, and jack pumps from 2,000 feet. Of course the deeper you pump from the lower the rate of pumping. Knowing the depth from which you will be pumping is important in selecting the right pump.

- Shallow Floodplain Wells - Missouri's streams that flow year around generally have groundwater available under the floodplain in a shallow aquifer (Figure 5). It is common to find water at about the same depth as the bottom of the stream channel. These shallow wells can be installed by the landowner or a certified well driller. Ask your well driller to obtain clearance for this type of well from: Section Chief, Wellhead Protection Section, P.O. Box 250, 111 Fairgrounds Road, Rolla, Missouri, 65402-0250, (573) 368-2165. Also, check with your local authorities for code and permit requirements.

Using a floodplain well not only provides a protected location for the pump but offers the livestock producer flexibility in setting up grazing pastures and watering locations. Shallow floodplain wells may not be as practical in Missouri streams that have sand bottoms instead of gravel and rock bottoms.

Figure 5 - *Groundwater Sources For Livestock Watering*



- Springs - Like ponds, springs often allow the use of the less expensive above ground pumps but it is often necessary to develop a way to hold the spring water to make it available for pumping. Ask your local Natural Resources Conservation Service office for assistance in developing your spring. If you have at least several feet of drop at your spring consider the use of a ram pump instead of a solar pump. Ram pumps require several feet of head and a constant supply of water, as is often available with a spring, but they are capable of pumping large volumes of water and are less expensive than solar pumps.

Once you have determined your water needs and have selected a suitable water source it is important to consider the amount of solar energy you have available to power a solar water pump.

The Available Solar Energy

Solar energy is often measured in sun-hours, 1 sun-hour being equal to the solar panel receiving one hour of 100% sunshine on a summer day at noon. Another way of describing a sun-hour is that it is equal to 1 kilowatt of electricity produced per square meter of solar panel. The number of sun-hours varies from day to day due to cloudy weather and from one season to the next because of the change in the angle at which the sun's rays strike the earth. Table 5 gives the average number of sun-hours that are available for each month of the year in Missouri. The angle of the sun and the average amount of cloudy weather at that time of the year are figured into these values. This table gives you a general understanding of the amount of solar energy available during the different times of the year. You do not need to be able to use this information to select a solar water pumping system. Instead use the advise that is available from the experts.

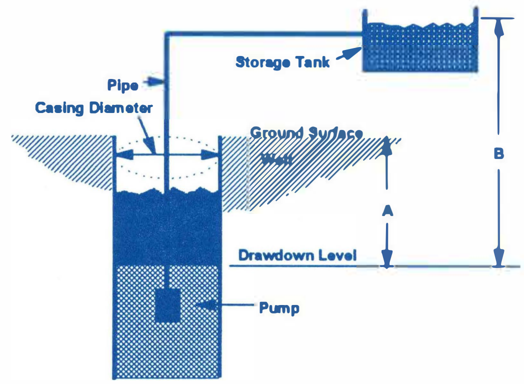
Table 5- Average Missouri Sun-hours

Month	Sun-Hours
January	2.3
February	3.0
March	4.0
April	5.1
May	5.9
June	6.5
July	6.6
August	5.8
September	4.6
October	3.6
November	2.3
December	1.9

Use of Expert Advice

To determine the solar pumping system that best fits your needs contact a reputable solar equipment dealer that provides technical assistance free of charge (see Appendix A). The dealer will combine the information you provide about your water needs and livestock operation with the information on solar energy available in your area, and help you select the system that best fits your needs. Your dealer will need some basic information in order to help you determine the type of system that will best serve your needs. The information you will need to provide is:

Figure 6 - Well Water System



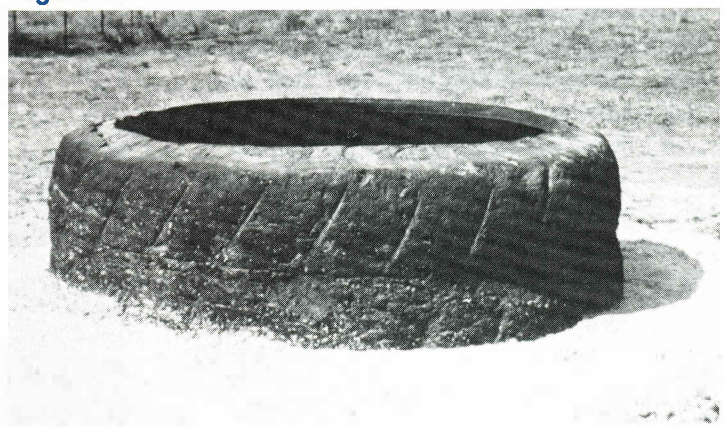
- Depth of the well or other water source, which is the distance from the ground level to the lowest possible drawdown level (A) of the water source, Figure 6.
- The total vertical distance which water is to be pumped, as measured from the lowest possible drawdown level (B) in the water source to the highest level of the watering tank, including the outlet pipe.
- The recovery rate of the well (in gallons per minute) if it is a well that yields a low volume of water. Refer to Appendix B for instructions on how to determine the recovery rate of your well.
- The inside diameter of the well casing, if a well is to be used.
- The average number of gallons of water needed daily for each month of the year and the particular use of the water. Refer to the example above and Table 3 for determining water needs.
- The quality of the water. (Include if it is silty, high in mineral content or contains a lot of algae growth.)
- Provide information on any water pumping equipment that is presently being used.
- The location of where the pumping system will be.
- Provide a sketch of how you want to lay out your watering system. Include the distances from the solar panels to the pump and from the pump to the watering tanks.

Water Storage

Water storage is an important consideration with direct drive solar pumping systems because the water needed during cloudy and night time periods must be pumped during sunny periods and stored for later use. It is recommended that about 3 days of your water needs be stored for this reason. So if your daily water need is 800 gallons you will need to provide 2,400 gallons of water storage. It should be noted that at least one manufacturer (see Appendix A) produces a system that is set up with a pressure tank and the controls needed to pump water on demand and under pressure, pumping water at a rate similar to that delivered by a standard 110 volt pumping system. This type of system is battery operated and does not need water storage tanks. However, expect to pay more for such a system as compared to other solar pumping systems.

Since water storage tanks can cost a significant amount of money it is worth looking at alternatives to purchasing manufactured tanks. One option is a water tank made from a discarded heavy equipment tire (Figure 7). These tanks will hold 300 to 700 gallons, depending on their size, and are inexpensive to construct. The tires can generally be obtained free of charge from roadway construction companies. Several hours of labor and about $75.00 worth of materials are needed to turn one of these tires into a water tank. These tire tanks are virtually indestructible and are a good way to recycle these tires. See Appendix C for instructions on building a tire tank.

Figure 7



Another water storage option that has been in use in the western United States is the "bottomless" stock tank (Figure 8). This is a 3 feet high galvanized steel ring that is assembled on site and placed about 1 foot deep into the ground. The inside of the ring is then lined with a plastic liner. These rings come in diameters of 15 to 42 feet and the tanks made from them range in capacity from 4,000 to 30,000 gallons. This type of water storage costs about 30% less than the commonly used galvanized steel stock watering tanks. These "bottomless" stock tanks are now available from distributors in Missouri (see Appendix A).

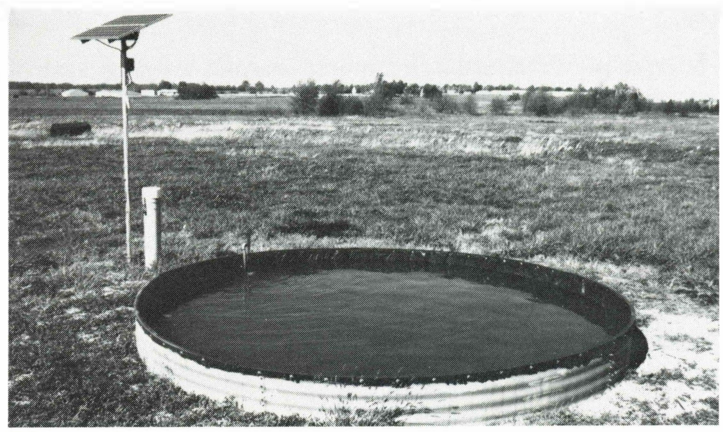
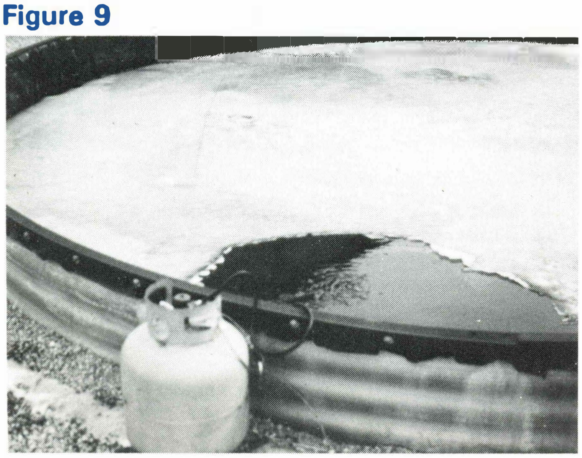


Figure 8

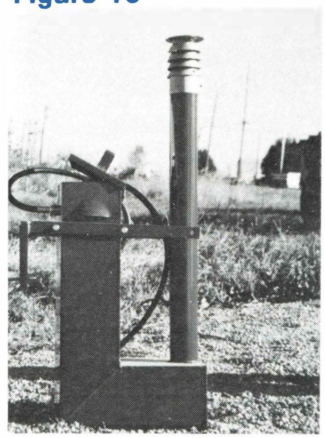
An important concern with storing water is the problem of freeze up in the cold weather months. The solar panels do not generate enough electricity to power a heater to keep the tank from freezing so other methods must be used. One method is to use a bubbler at the bottom of the water tank to keep an area ice free (Figure 9). This can be done by attaching an air line to a propane tank and attaching an aquarium type air stone to the other end of the air line. To prevent the propane from emptying too fast care must be taken to open the tank valve only enough to allow a steady flow of bubbles. In an outdoor setting there is no danger created by this small amount of propane and a 20 pound tank will commonly last for more than 30 consecutive days. A solar powered air bubbler is also available (see Appendix A).

Figure 9



Another method of keeping an area ice free is to pump water at regular intervals around the clock. This is especially effective when the water source is an underground well, since underground water temperatures are about 56^0 F. This periodic pumping is accomplished by using a battery operated system that is equipped with a timer that can be set to turn the pump on and off at scheduled times.

Figure 10



An area can also be kept ice free with the use of a propane stock tank heater (Figure 10). These heaters attach to the side of the stock tank and are usually hooked up to propane tanks that are 100 pounds or larger. You can expect to use several of these 100 pound tanks in an average Missouri winter. The propane bubbler described earlier uses far less propane and does not require the purchase or maintenance of the heater.

Maintenance

The amount of maintenance required by solar watering systems depends on the type of system. Direct drive systems will require less maintenance because there are few components to break down. In fact solar panels rarely need maintenance; it is the batteries, pumps, and other components that require periodic maintenance. When selecting a solar water pumping system it is important to consider the level of maintenance required for the various system components you are considering. Check with your dealer about protection from lightning and with your insurance agent to determine how this equipment will be insured.

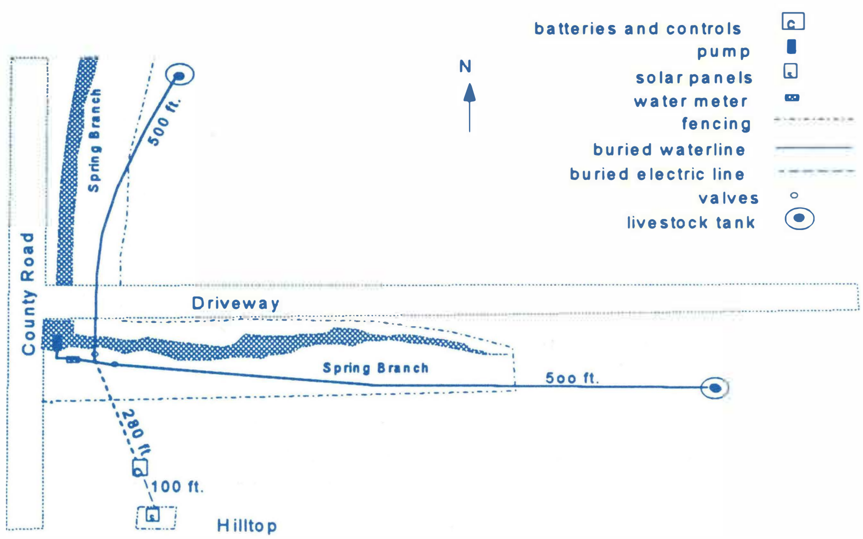
The amount of maintenance required is also dependent upon how well your system is set up. Take the time to prevent excess maintenance by doing such things as fencing livestock away from the solar panels, placing the solar panels on a mast high enough to be out of flood waters, and screen the pump from sand and silt.

Gary's Dairy Farm

Gary is a dairyman who milks about 65 cows near Springfield, Missouri. In addition to his milk cows, he usually has several heifers on pasture. Gary was watering his cows in his spring branch when they were out to pasture and watering them twice a day with well water when they were at the barn for feed and milking. The herd was obtaining about half of its daily water needs at the barn and half from the spring branch. Gary wanted to fence his cattle from the spring branch but he needed a way to pump water to them. Figure 11 shows the watering system that was installed to provide water in two pastures.

Figure 11 -

GARY'S SOLAR WATERING SYSTEM



Gary's system is equipped with batteries, and a timer is included with the standard controller so that the pump can be turned on and off as many as 8 times a day. He wanted to be able to pump periodically throughout the day and night during freezing weather to prevent system freeze up. The cattle would still be getting half of their water at the barn so a system was selected that would provide ample water to meet the other half of their water needs. At each watering location water is being stored in tire tanks.

Table 6 shows the daily number of gallons the system was designed to pump and the average number of gallons the system actually pumped over the 2.5 year time period it was monitored. It should be noted that a watering system should always be designed to pump more water than is thought to be needed. This allows a safety margin for those circumstances that cannot be foreseen. Gary's cattle had ample water even though the actual gallons pumped was sometimes lower than the gallons projected to be pumped.

Gary's solar water pumping system is more complicated than most producers need but it does show what can be done with solar powered pumps. The cost of this system is displayed in Table 7. Note that the Missouri Department of Conservation shared 50% of the cost of this project. Check with your local Department of Conservation office or Department of Natural Resources Soil and Water District office to find out if financial assistance is available to help you install a watering system.

Maintenance on this project was minimal except for the pump which followed the pattern of slowly losing its pumping capacity until replacement of the diaphragms was required. The dealer and manufacturer feel that too much sand was being pumped which was wearing out the diaphragms. A sand shroud has been added to the pump to alleviate this problem. All equipment replacements needed to get through this problem were handled under warranty at no cost to Gary.

Table 6 - Performance of Gary's System

MONTH	PROJECTED GALLONS	ACTUAL GALLONS PUMPED
JANUARY	1024	1010
FEBRUARY	1152	1246
MARCH	1152	1311
APRIL	1152	1263
MAY	1152	1041
JUNE	1152	1457
JULY	1536	1910
AUGUST	1408	1417
SEPTEMBER	1408	1469
OCTOBER	1408	1271
NOVEMBER	1088	1099
DECEMBER	1024	953

Several months after setting up the system Gary decided to expand the size of his herd. To meet the increased water needs, two additional solar panels as well as two batteries were added to the system. This provided a 50% increase in Gary's ability to pump water.

Table 7 - Cost of Gary's project when installed in 1993.

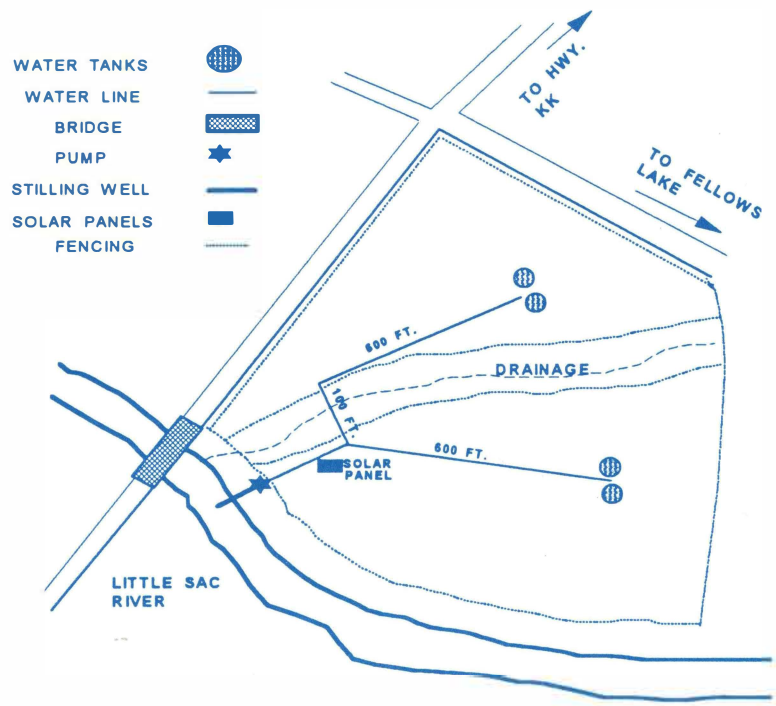
ITEM	AMOUNT	COST
Solar Pumping System	1	$2,537.00
4 panel array		
controller/timer		
2 batteries		
100 ft. cable		
pump		
steel box		
shipping		
Underground wire	285 ft.@ $.99/ft.	$282.00
Plumbing Supplies		$530.00
1,000 ft. pipe		
connectors		
2 valves		
Trenching	22 hrs.	$880.00
Water Tanks	2	$200.00
concrete		
crushed rock		
	TOTAL -	**$4429.00***
	Gary's Cost -	**$2214.50**

*Missouri Department of Conservation cost shared 50% of this project.

Springfield City Utilities Project

Springfield City Utilities, the supplier of drinking water for Springfield, Missouri, has joined with the Watershed Committee of the Ozarks, Natural Resources Conservation Service, and Missouri Department of Conservation to set up a planned grazing demonstration below Fellows Lake on the Little Sac River. The system was set up to provide water for 20 head of beef cattle. The layout of the system is shown in Figure 12.

Figure 12 - Springfield City Utilities Project



The pump on this site is powered directly by the solar panels and controller so no batteries are needed. Three to four days of water is stored at the two watering sites. One tire tank and one galvanized steel tank are used at each watering location.

Original plans were to drill shallow wells in the floodplain for water sources. However, sufficient water was not available at the proposed well locations. Water is being supplied from under a gravel bar in the river. A stilling well, similar to that shown in Figure 4, is being used to collect water for the pump.

The solar panels are located 150 feet from the river channel. This distance prevents any shading of the panels from the trees that are growing near the river. The panels are mounted 8 feet above the ground on top of a steel pipe mast, which keeps them out of flood waters.

This water pumping system has performed very well by supplying enough water to support 40 head of beef cattle instead of the 20 head it was set up to supply with water (Table 8). In the two years it has been in service the only maintenance that has been required was the replacement of the pump. The pump was damaged when water lines froze up and the pump was allowed to run. Burying the water lines below the frost line or shutting off the pump would have prevented this breakdown. The cost of this system is shown in Table 9.

Table 8 - Gallons of water projected to be pumped and the average gallons pumped.

MONTH	PROJECTED GALLONS	ACTUAL GALLONS PUMPED
JANUARY	458	479
FEBRUARY	458	842
MARCH	458	985
APRIL	518	1139
MAY	561	960
JUNE	604	1231
JULY	648	1136
AUGUST	604	1158
SEPTEMBER	561	1005
OCTOBER	458	932
NOVEMBER	458	705
DECEMBER	458	481

Table 9 - Cost of Springfield City Utilities Direct Drive System when installed in 1995.

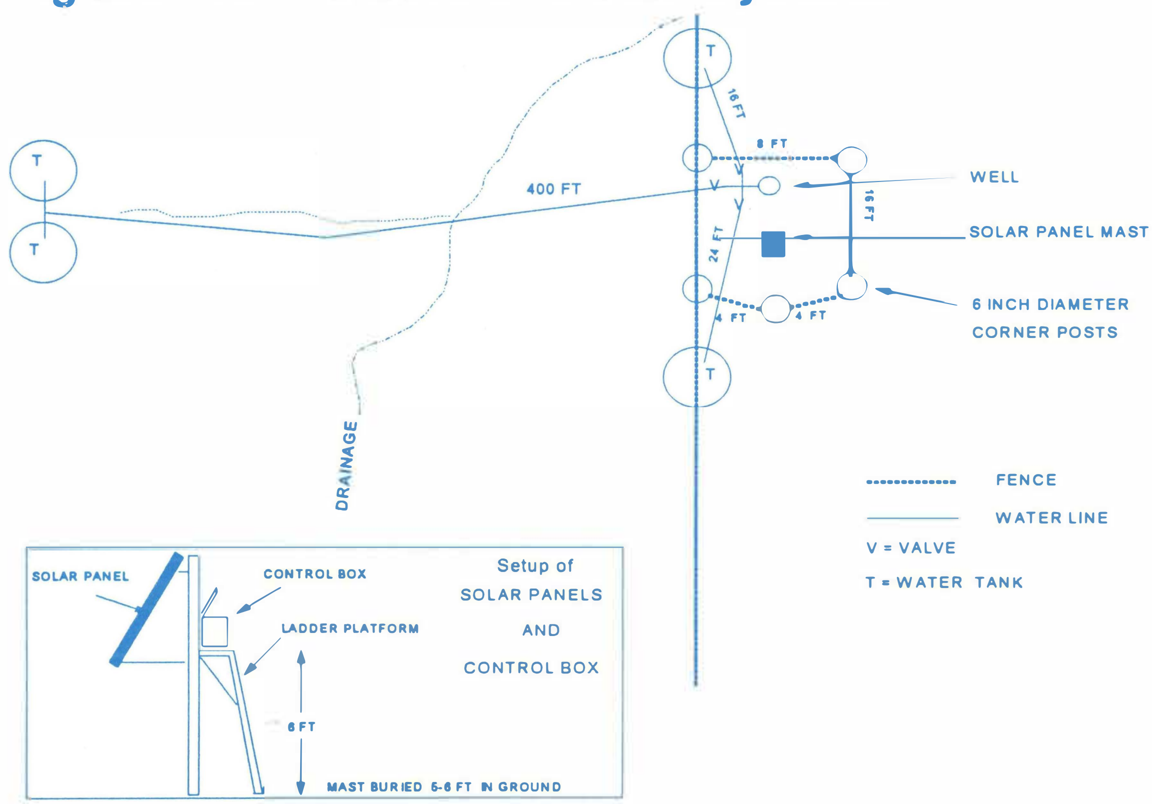
ITEM	AMOUNT	COST
RanchPump I System submersible pump 73 watt panel controller	1	$1050.00
Water tanks	4	$550.00
Water lines	1400 ft.	$1400.00
Stilling well	1	$550.00
Misc. hardware		$100.00
	Total -	**$3650.00**
	Landowner Cost -	**$912.50[1]**

1 - Cost to landowner if eligible for 75% cost sharing through federal or state programs that were available at the time this booklet was printed.

David's Battery Equipped System

David is a dairy farmer with a 50 cow milking herd who is setting up his pastures in a rotational grazing system. He has a hayfield in the Niangua River floodplain that he would like to convert to pastures but he needed a source of water. Figure 13 shows how his solar water pumping system was set up.

Figure 13 - David's Solar System



David's system is equipped with batteries and a timer so that the submersible pump can be turned on and off as many as 16 times a day. This allows periodic pumping throughout the day and night during cold weather periods which prevents system freeze up. Water is pumped from a well in the floodplain that is 17 feet deep. All waterlines are buried below the frost line and supply both tire tanks and plastic tanks made from discarded storage tanks. The solar panels , controller, and batteries are mounted on a mast that is above the elevation of the highest flood recorded for the Niangua River in this area. The system was designed to run 6 days with low sunlight. Table 10 shows the performance of this system over a 2 year period.

Table 10 - Gallons projected to be pumped and the average number of gallons actually pumped.

MONTH	PROJECTED GALLONS	ACTUAL GALLONS PUMPED
JANUARY	864	1089
FEBRUARY	832	942
MARCH	832	876
APRIL	864	1022
MAY	960	1353
JUNE	864	942
JULY	960	1145
AUGUST	960	1239
SEPTEMBER	960	1132
OCTOBER	960	1260
NOVEMBER	864	1035
DECEMBER	864	964

As shown by these data, this system has exceeded the projected average output. Normal maintenance included annual replacement of the diaphragms in the pump and periodic cleaning of the pump screen. A timer and electrical relay had to be replaced due to a lightning strike, at a cost of about $100.00. A breakdown of the cost of the system is given in Table 11.

Table 11 - Cost of David's project when installed in 1993.

ITEM	AMOUNT	COST
Solar Pumping System	1	$2,539.00
4 panel array		
controller/timer		
2 batteries		
100 ft. cable		
pump		
shipping		
Waterline Installation		$450.00
400 ft. pipe		
connectors		
2 valves		
Trenching		
Well cap and pitiless adapter		$150.00
Water Tanks	4	$200.00
concrete		
crushed rock		
Well		$650.00
	Total -	**$3989.00**
	David's Cost -	**$1994.50**[1]

[1]Missouri Department of Conservation cost shared 50% of this project.

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APPENDIX A

Suppliers of Solar Related Equipment

This list of suppliers are those that the author was able to locate as of the printing of this handbook. This list is not an endorsement of these suppliers or their equipment.

Dealers of Solar Water Pumping Systems

Photocomm
7681 East Gray Rd.
Scottsdale, Arizona 85260
1-800-544-6466
Contact: Wil Herndon

Sunelco
100 Skeels St.
P.O. box 1499
Hamilton, Montana 59840-1499
1-800-338-6844

Photovoltaic Services Network
165 South Union
Suite 260
Lakewood, Colorado
1-800-836-8951

The following are names of dealers supplied by:

Heartland Solar Energy Industries Association, P.O. Box 894, Topeka, Kansas 66601, (913) 295 - 4911.

Midwest Conservation Systems Inc.
P.O. Box 397
Silver Lake, Kansas 66539
1-800-696-4509
Contact: Ed Irvine

Solar Electric Systems of Kansas City
13700 W. 108th St.
Lenexa, Kansas 66215
(913) 338-1939
Contact: Bill Roush

The Sun (Solar Utility Network)
406 State St.
Augusta, Kansas 67010
1-800-689-7908
Contact: Richard Richardson

Grassland Supply, Ltd.
R.R. 3, Box 6
Council Grove, Kansas 66846
(316) 767-5487
Contact: Don Day

Kansas Wind Power
13569-214th Rd.
Dept. KS
Holton, Kansas 66436
(913) 364-4407
Contact: Bob McBroom

Ozark Solar
314 East Spring
Neosho, Missouri 64850
(417) 451-4756
Contact: Travis Creswell

Dealer of solar air bubbler:

OK - Water
3824 East ^th Ave.
Stillwater, Oklahoma 74074
1-800-750-2837

Supplier of bottomless stock tanks:

Pride of the Farm
Grain Bin Division
P.O. Box 2000
Houghton, Iowa 52631
1-800-882-0842

APPENDIX B

Determining a Well's Recovery Rate

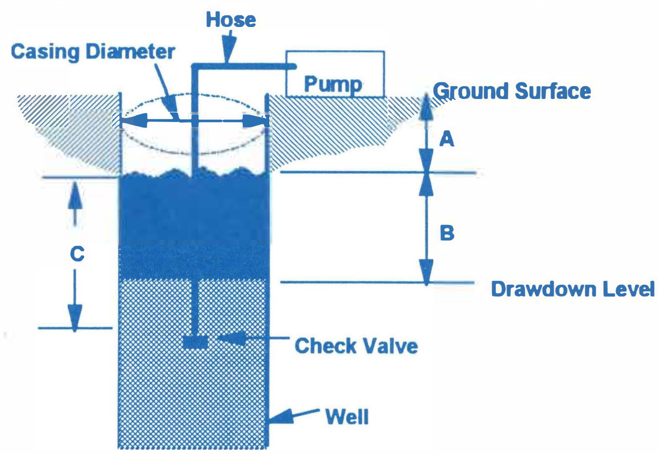


Figure 1 - Well and Test Pump

In order to determine the recovery rate of a well several items will be needed: a pump that is capable of pumping at a rate at least as high as the rate required to meet livestock watering needs, a heavy duty hose that will not collapse under the pumping suction, a check valve for the hose, pencil and paper, stopwatch, tape measure, and a way to measure the water level in the well. A weighted line with one-foot increments marked on it will work. This test should be done at the driest time of the year you expect to be using the well.

Referring to Figure 1, first measure and record the depth of the water level in the well (A), the depth to which the pump intake hose is down in the water (C), and the inside diameter of the well casing. Then pump water out of the well and time how long it takes to fill a one gallon container, this value is used to determine how many gallons per minute are being pumped. Leave the pump run to see how far it will draw down the water level and record the level at which the water level stabilizes (A+B), assuming it has not drawn the well below the pump intake. You will always want to hang your solar water pump intake below this level so it is always in water.

If it does draw the water level below your pump intake, stop the pump and record the time it takes for the water level to recover to its original level (A). Along with the values for the inside diameter of the casing and the length of casing that was dewatered (C), the gallons of water the well recovered can be determined using the following table:

Inside Diameter of Casing	Gallons Per Foot of Depth
4 inch	0.66 gallons
5 inch	1.04 gallons
6 inch	1.50 gallons
8 inch	2.66 gallons
10 inch	4.19 gallons
12 inch	5.80 gallons

The gallons of water recovered is then divided by the number of minutes it took for the well to recover, this value is your well's recovery rate in gallons per minute.

APPENDIX C

Making A Tire Tank

The tires from heavy equipment, such as earth movers used in road construction, are good for making into water tanks because they are usually free (if you will haul them), very durable, able to hold large volumes of water, and are a good use for these discarded tires. ***However, it is essential that you do not use a steel belted tire, or you will not be able to cut out the sidewall by the method described below.*** The biggest challenges to making one of these tires into a water tank is finding a way to haul it home, place it at your watering site, and cutting the sidewall off of the side that will be used as the top of the water tank. Cutting out the sidewall for the top of the tank must be done so that cattle can easily reach the water. The hauling and placing jobs are a challenge because of the weight and size of the tires. ***Safety is a serious concern so it is essential that you have the proper equipment needed to load, haul and unload these tires.***

Cutting Out the Sidewall

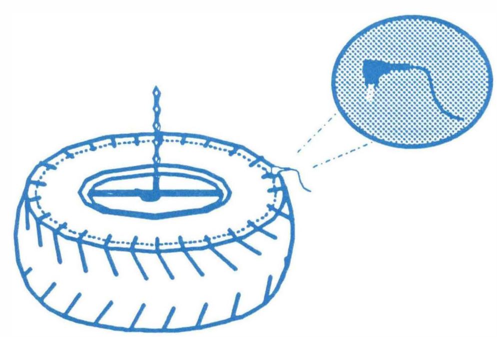
Tools Needed: a reciprocating saw with a knife blade or a very fine-toothed blade, an electric drill, a flat nail-pulling bar, 2 cold chisels that are about 12 inches long, a steel bar that is longer than the diameter of the tires rim hole, and a block and tackle or other safe method of hoisting a heavy object. ***NOTE: The following method is much easier and safer than using a chain saw.***

Method

Step 1 - position your hoisting equipment over the center of the tire, attaching the hoist chain to the center of the steel bar. Position the steel bar across the center of the rim hole on the inside of the tire. Raise the hoist to put enough pressure on the steel bar to hold it in place but not enough to lift the tire. The steel bar will now hold up the weight of the sidewall as it is cut away from the tire.

Step 2 - Drill a hole in the sidewall near the outside edge of the tire in the path that the saw blade will follow. The hole must be large enough for the saw blade to pass through.

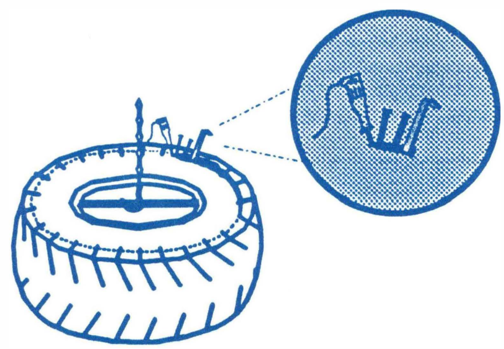
Steps 1 and 2 - Preparing to Cut the Sidewall



------------ = Cutting Path

Step 3 and 4 - Cutting the sidewall.

Step 3 - With the saw blade properly inserted in the saw, place it in the drilled hole and begin cutting out the sidewall of the tire.



-------- = Cutting Path

Step 4 - The key to being able to cut this heavy rubber tire is to not allow the blade to become pinched as you cut. To avoid pinching the blade insert one of the cold chisels in the cut immediately behind the blade as the cut is being made. As the blade cuts forward place the other cold chisel immediately behind the blade and as the cutting continues remove the first chisel and place it in the cut behind the blade.

Continue to advance the chisels up behind the blade as the cutting continues in order to keep the blade from becoming pinched. The flat bar is used as a pry bar for spreading the cut open to allow the chisels to be removed as the cutting continues around the tire.

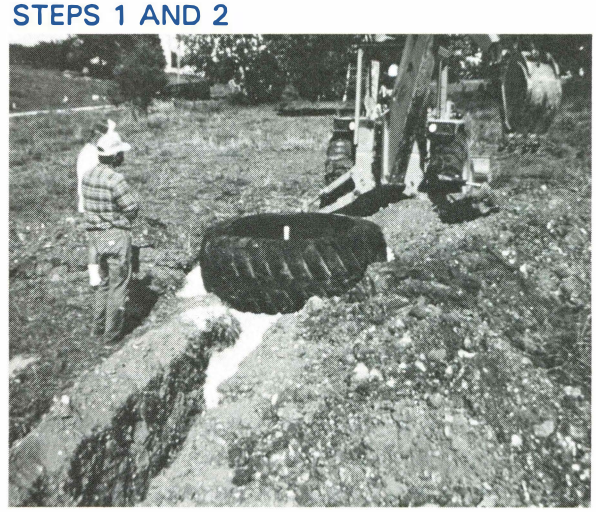
Step 5 - As the cutting nears completion it may be necessary to reposition the steel bar to insure that it holds up the weight of the sidewall as it is cut away from the tire. ***Because the sidewall is quite heavy, caution should be used as the cut nears completion.***

Installing the Tire Tank

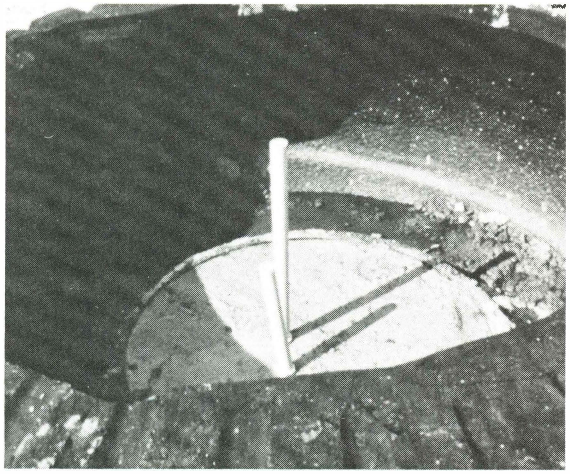
Step 1 - Trench in the water and overflow pipes to the water tank location 1.5 to 3.0 feet deep to provide frost protection and extend the pipes vertically to above ground level. If you will be dragging the tire into place cut off the water lines at ground level. Cap them to prevent dirt or debris from falling into the pipes.

Step 2 - Backfill the trench under the tire location with crushed rock or some other solid fill and place the tire, centering the waterlines in the rim hole.

STEPS 1 AND 2



STEPS 3 AND 4



Step 3 - Cut the water lines off at the same level as the top of the rim hole and attach coupler fittings to the water lines. Cover the coupler fittings so that concrete will not fall into the pipes. When you pour the rim hole full of concrete these coupler fittings will be flush with the surface of the concrete and will be used to install replaceable stand pipes for each of the water lines.

Step 4 - Fill the space under the rim hole area with concrete and finish it off at the top level of the rim hole. You can get by with less concrete if you partially fill the space with crushed rock.

Step 5 - Place the precut stand pipes in the coupler fittings and allow time for the concrete to harden before water is added to the tire tanks. Screen the opening of the overflow pipe to prevent clogging of the pipe with debris and algae. In the future, if these standpipes are broken they can be removed from the coupler and replaced.

Step 6 - You may want to place crushed rock around the tire tank to prevent the area from becoming a mud hole after rains and heavy livestock use.

For additional copies of this handbook call or write : Missouri Department of Conservation, P.O. Box 180, Jefferson City, MO 65102 Phone: (573) 751 - 4115 Streams Unit

MISSOURI DEPARTMENT OF CONSERVATION